Miniature Ground Penetrating Radar, CRUX GPR

Soon Sam Kim, Steven R. Carnes, Albert F. Haldemann, JPL

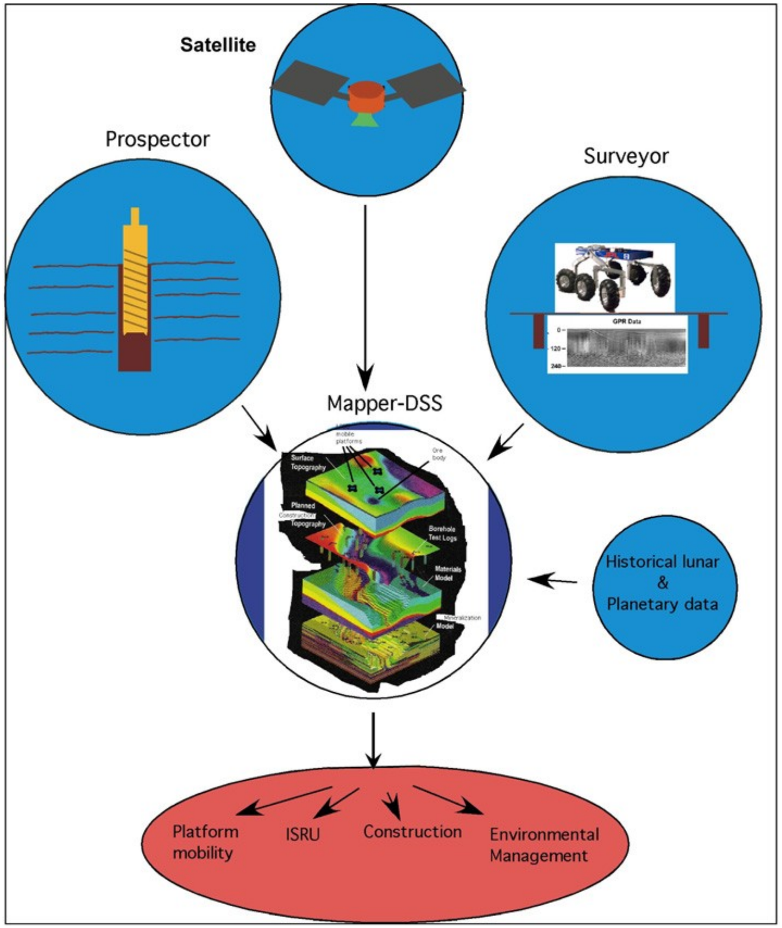
Christopher T. Ulmer, Ulmer Systems,

Eddie Ng, A Star Technologies,

Steven A. Arcone, US CRREL

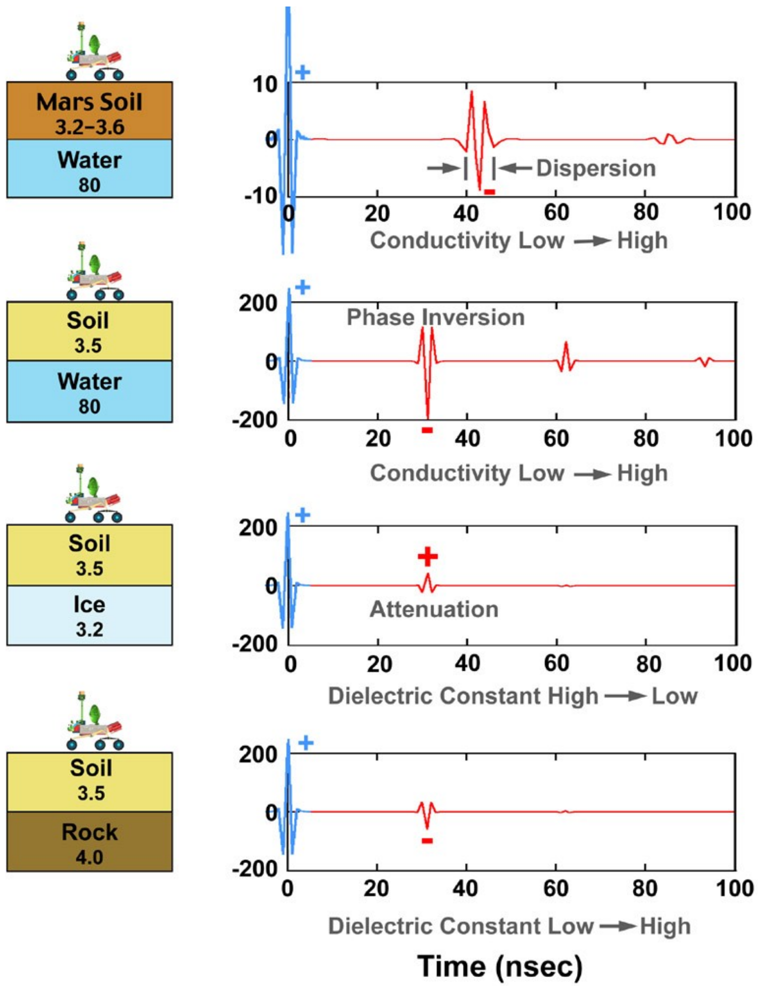
Construction & Resource Utilization Explorer (CRUX)
Instrument Suite for Lunar Missions

- CRUX: Instrumented drill (Prospector) and geophysical (Surveyor) regolith characterization instrumentation suite, and data integration-interpretation decision support system (Mapper-DSS).
- Miniature GPR as one of the CRUX Surveyor Instrument Suite.



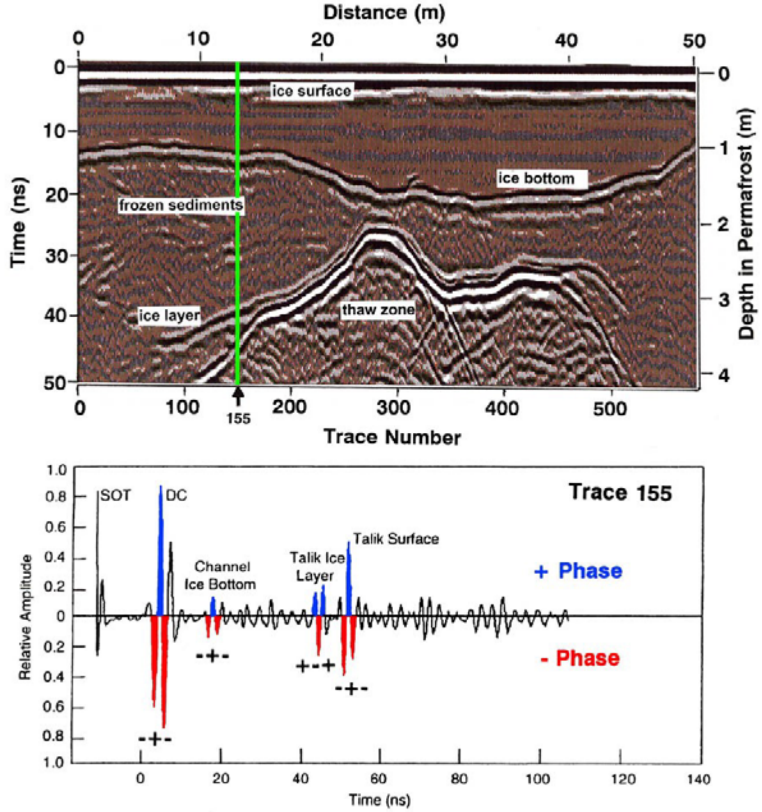
Principle of GPR

GPR Reflections reveal dielectric properties through changes in phase, amplitude & dispersion



The reflection patterns
will depend upon
the ratios of dielectric constants,
conductivity and
permeability of layers.

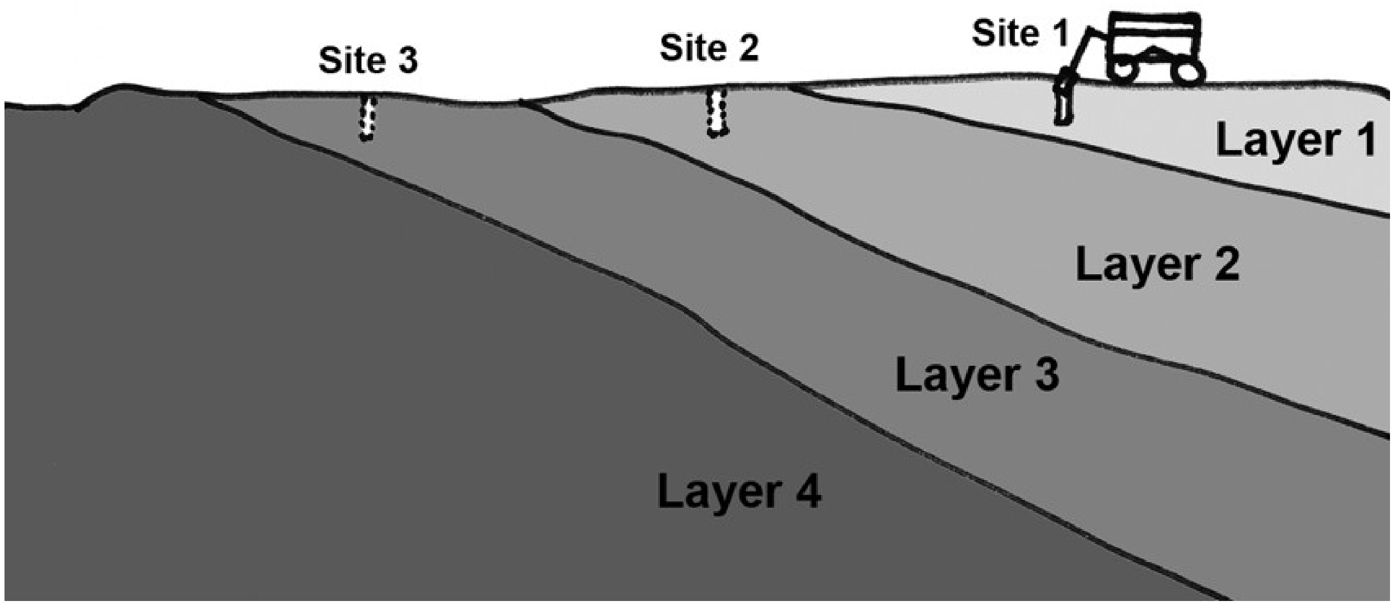
Principle of GPR



The phase opposition between the reflections from the ice layer and either the channel ice bottom or the talik surface is consistent with the sequences of higher ε (frozen sediments) over lower ε (ice) vs., lower ε (ice) over higher ε (unfrozen or partially frozen sediments), respectively.

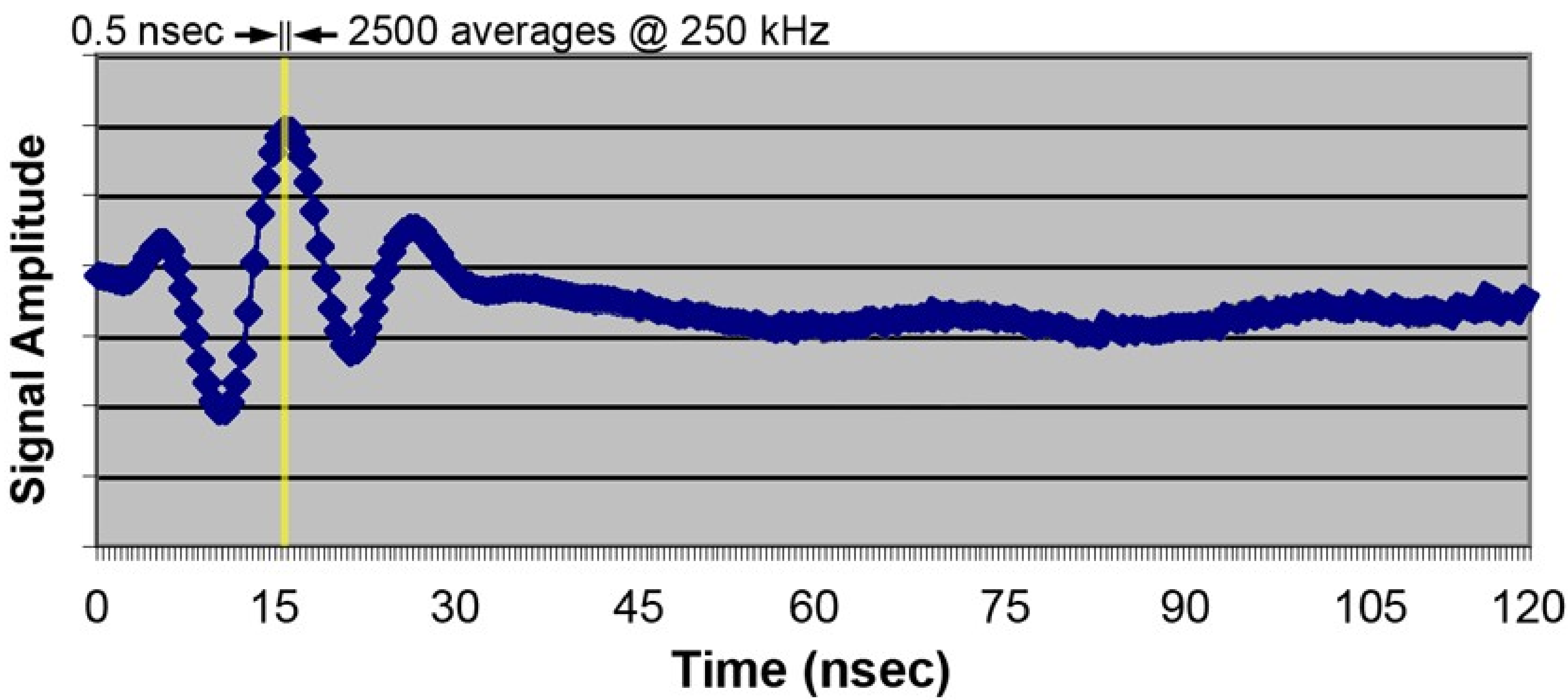
GPR for Lunar Missions

- Characterization of subsurface stratigraphy
  - Dielectric contrasts between layers
- Provide guidance for a trench based sampling for ISRU
- GPR will be deployed with a rover
  - Electronics in Rover Warm Electronics Box
  - Antenna placed under belly of a rover



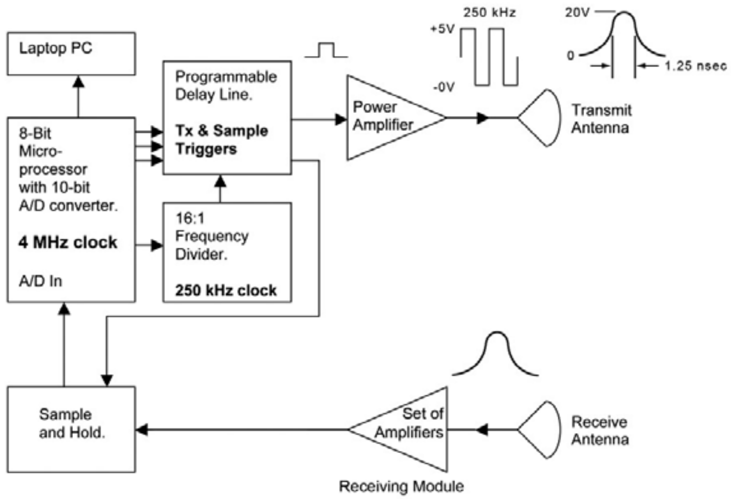
CRUX GPR Summary

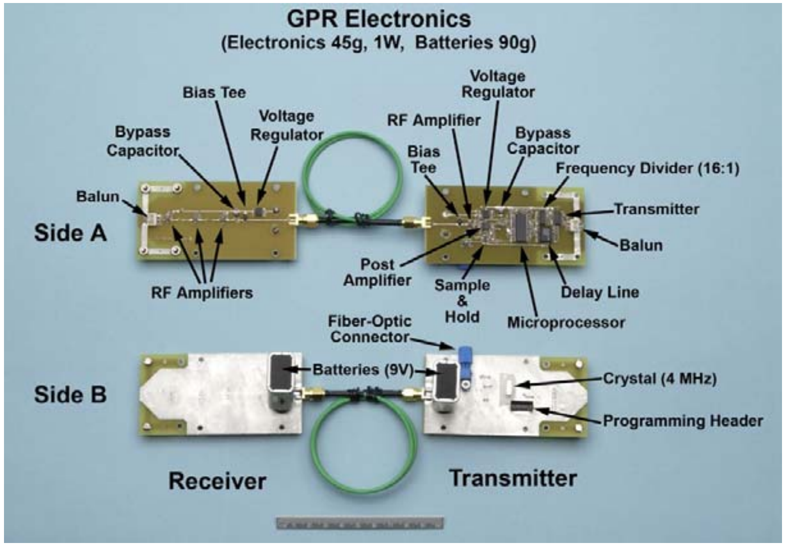
- **Miniature Impulse GPR**
  - **@ 800 MHz Center frequency**
  - **Depth of Penetration, 5 m; Resolution, 15 cm**
  - **Low power (1 W) with box-car mode of sampling**

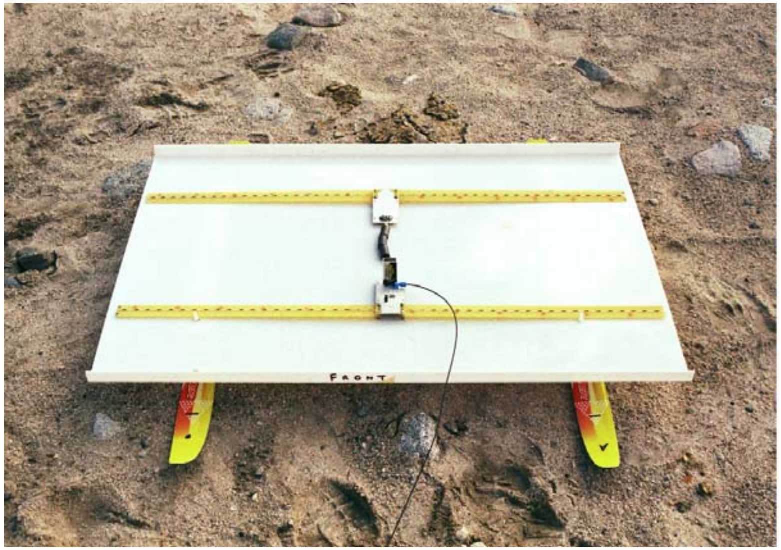


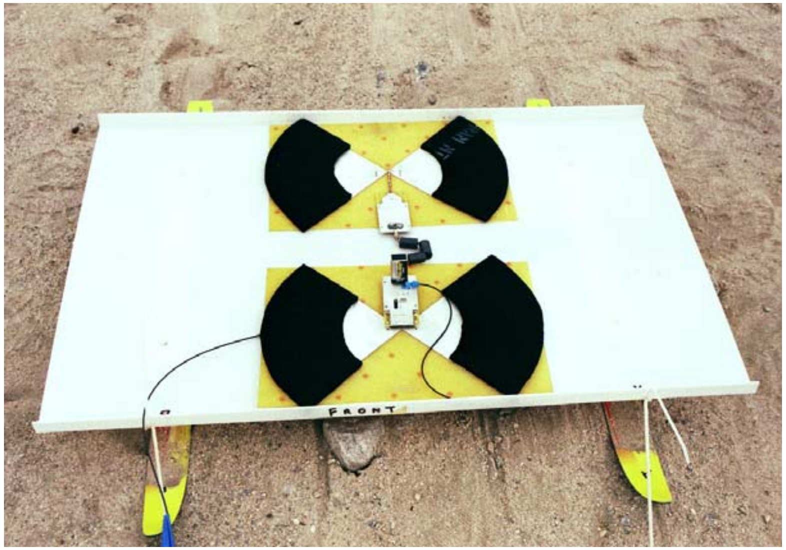
Miniature CRUX GPR

Hardware





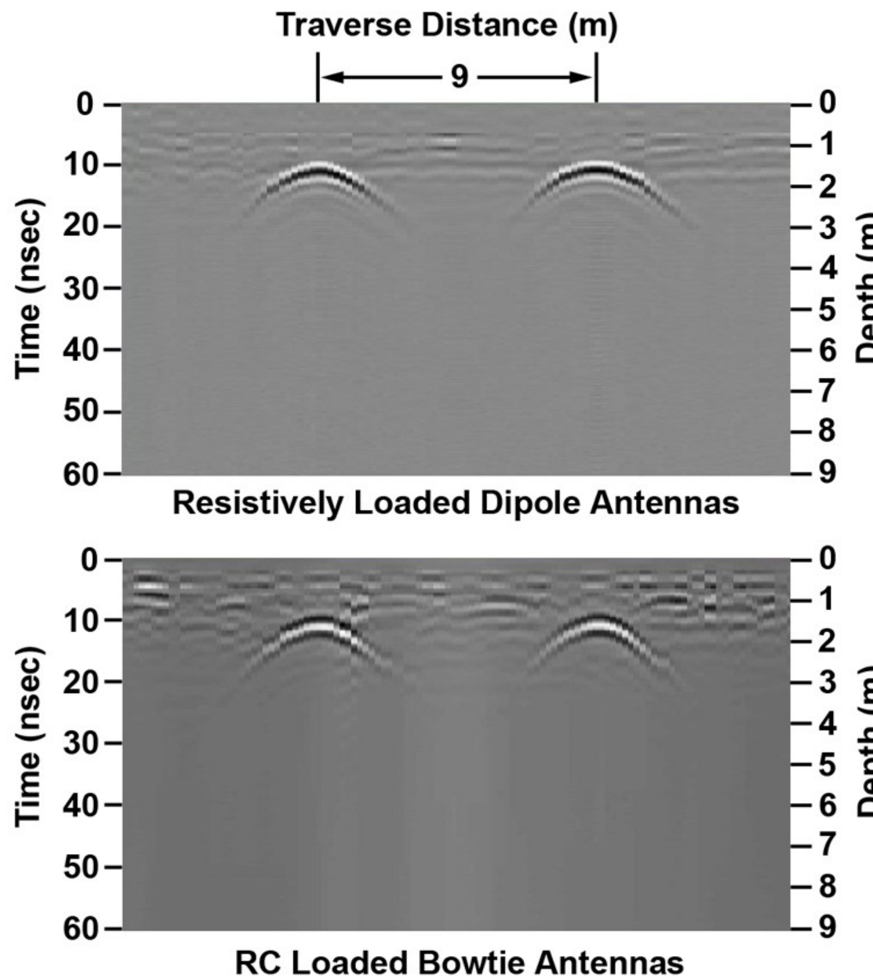




The sled (66 cm x 98 cm)

CRUX GPR Field Testing

Indio, CA



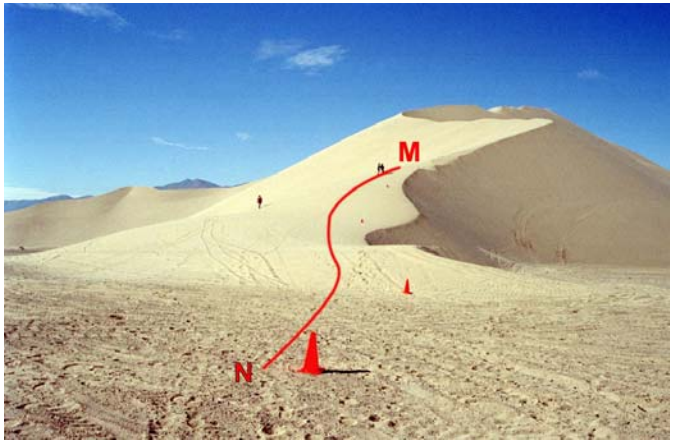
<u>Quester Gas Pipe lines</u>

2 pipes @:

1.5 m depth
76 cm diameter
9 m separation

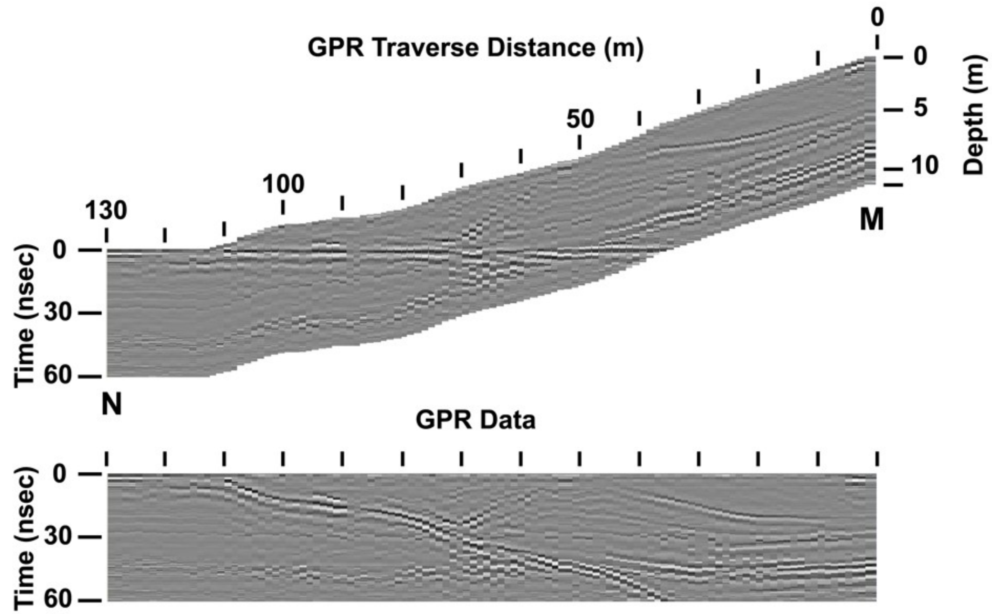
CRUX GPR Field Testing

Dumont Dunes, CA



Wind blown sand
deposited on an alluvial plain

GPR data was manipulated to match the contour of the dune and show the horizontal plain at the bottom of the dune.



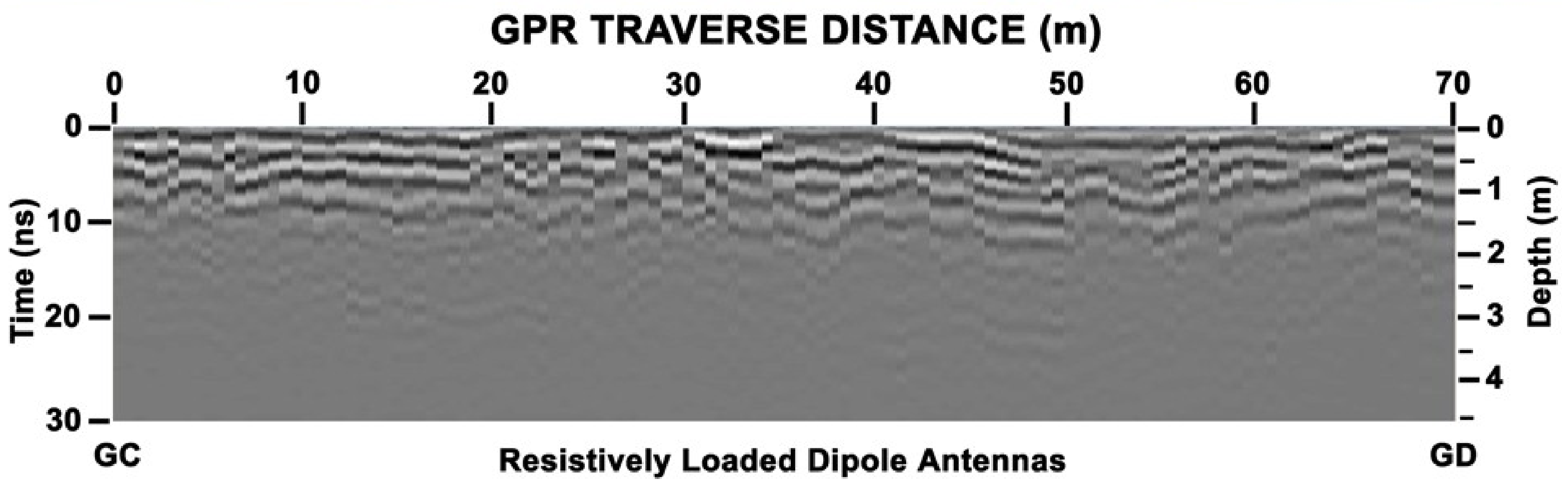
CRUX GPR Field Testing

Hawaii Volcano's National Park

Kilauea Southwest Rift

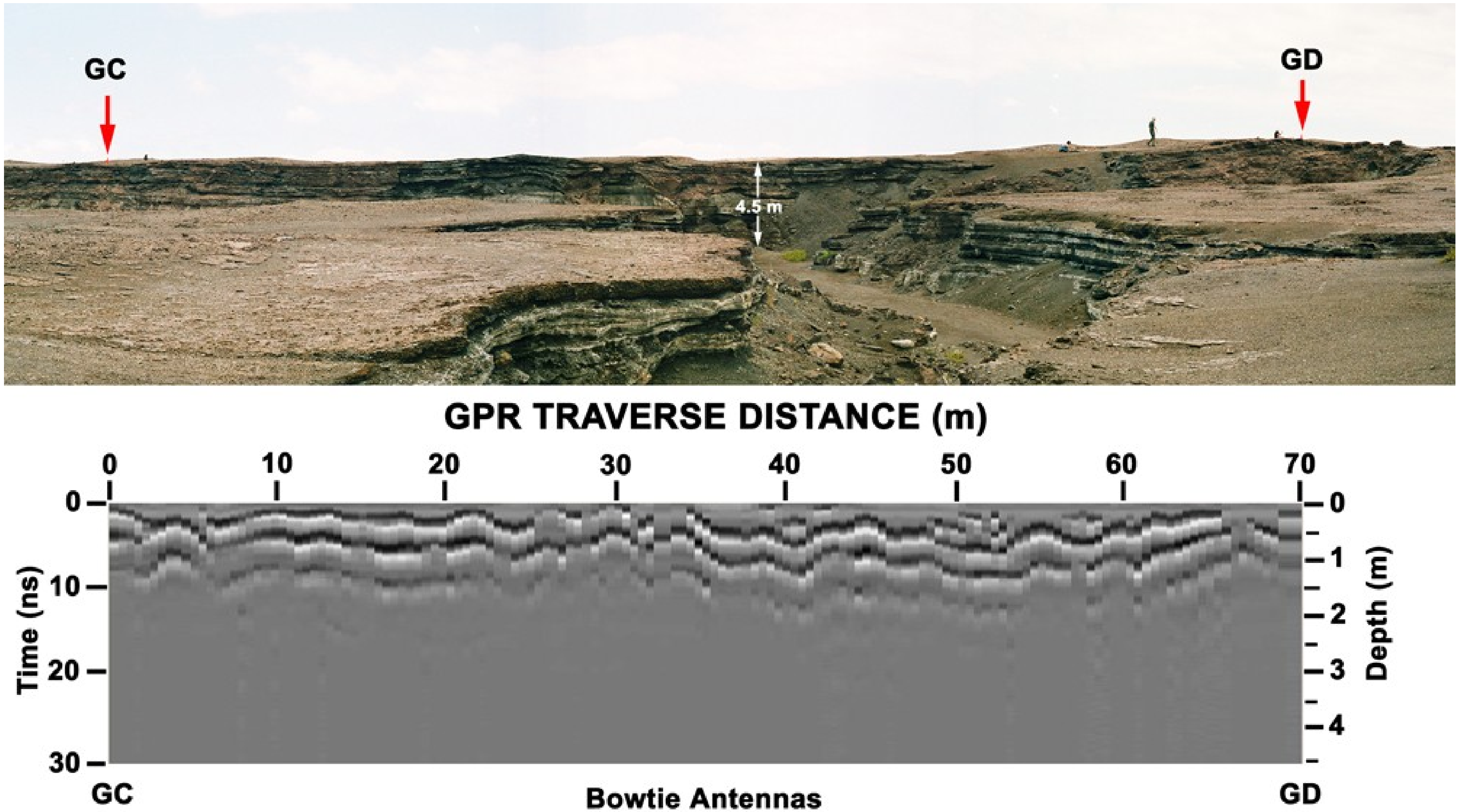
CRUX GPR Field Testing

Hawaii Volcano's National Park



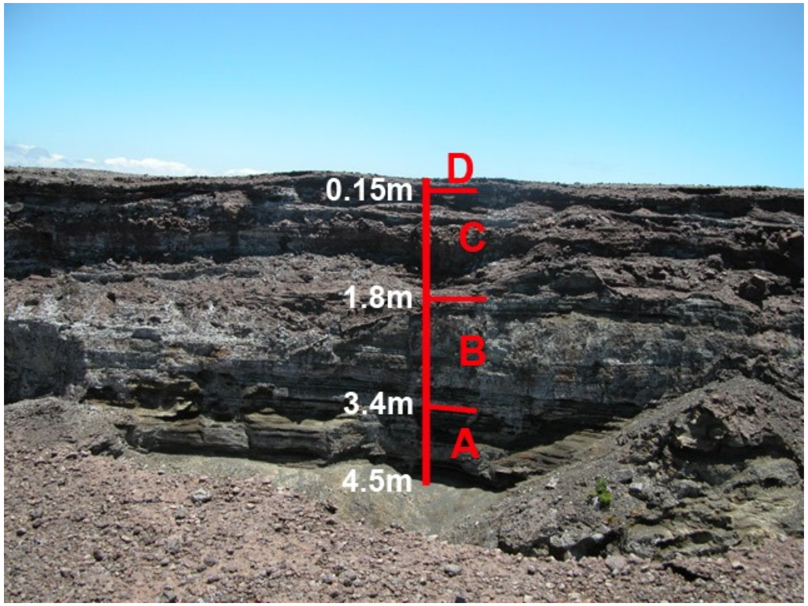
CRUX GPR Field Testing

Hawaii Volcano's National Park



CRUX GPR Field Testing

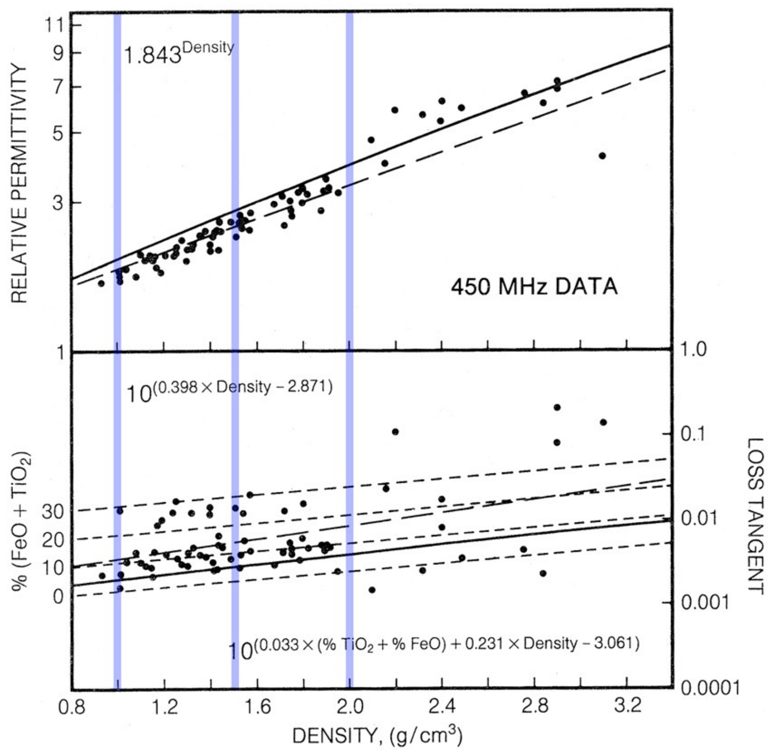
Hawaii Volcano's National Park



- **Layers of Volcanic Ash**
  - **Basaltic; pyroxene, plagioclase, olivine, magnetite and hematite**
- **Layer A**
  - **Laminated deposits of fine grained ash**
- **Layer B**
  - **Fine grained ash with heavy opaline silica sementation**
- **Layer C**
  - **Ash beds with silica cementation and larger cobbles**
- **Layer D**
  - **Desert pavement**
  - **Cobble sized rocks of basaltic composition with fine ash and aeolian dust**

Lunar Application of GPR

Dielectric Properties of Lunar Soil from Apollo Missions



Dielectric Properties #

		ε'	tan δ	dB/m @ 800 MHz
Moon [6]	ρ = 1.0	1.843	0.0032	0.31
	ρ = 1.5	2.502	0.0041	0.48
	ρ = 2.0	3.397	0.0054	0.72
Earth [3]	Sandy Soil Dry	2.55	0.0093	1.08
	Loamy Soil, Dry	2.46	0.0055	0.63
	Clay Soil, Dry	2.36	0.019	2.12
	Magnetite Soil, dry	ε'	tan δ	dB/m @ 800 MHz
		3.50	0.019	8.17
		μ'	tan δ_m	
		1.07	0.039	

Dielectric properties (radar attenuation rate, dB/m) of Lunar materials comparable with earth soil, between dry sandy and loamy soil